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Specialised Petroleum Services Group Limited
Arnhall Business Park
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AB32 6TQ

Patents ADP number *(if you know it)* 8460784002

If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom

4. Title of the invention

Actuating Mechanisms for Downhole Tools

5. Name of your agent *(if you have one)*

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Actuating Mechanisms for Downhole Tools

The present invention relates to downhole tools as used in the oil and gas industry and in particular, though not exclusively, to a mechanism for moving a sleeve in a circulating tool to start or stop circulation of fluid.

While many downhole tools operate continuously through a well bore e.g. scrapers and brushes as disclosed in US 6,227,291, it is more desirable to provide a tool which performs a function only when it has reached a preferred location within a well bore. An example of such a tool would be a circulation tool as disclosed in WO 02/061236. The tool provides a cleaning action on the walls of the casing or lining of the well bore. The cleaning action is only required after the casing has been brushed or scraped and thus the tool is designed to be selectively actuated in the well bore. Such tools provide the advantage of allowing an operator to mount a number of tools on a single work string and operate them individually on a single trip in to the well bore. This saves significant time in making the well operational.

Tools which are selectively actuable in a well bore commonly operate by having an element which can be moved relative to the tool when in the well bore. In the circulation tool of WO 02/061236, the element is a sleeve located in the cylindrical body of the tool. When run in the well, the sleeve is held in a first position by one or more shear screws. To actuate the tool, a drop ball is released from the surface of the well through the work string. On reaching the sleeve, the ball blocks the flow of fluid through the tool and consequently pressure builds up until the shear screws shear and the sleeve is forced downwards. The movement of the sleeve is then stopped when a lower ledge of the sleeve contacts a shoulder on the internal surface of the tool body.

Such tools have a number of disadvantages. As the drop ball must block the flow of fluid through the tool to operate, the tool can only operate to turn circulation 'on' and fluid flow through the bore of the tool cannot be restarted. These tools further prohibit the use of any other tool located on the work string below the tool, particularly if the lower tool is hyraulically operated e.g. a packer.

One tool which has been developed to operate repeatedly is that disclosed in US 4,889,199. This tool comprises a tubular body having a radial port into which is located a sleeve having a matching radial port. The sleeve is slidably mounted and its action controlled from a deformable drop ball biasing the sleeve against a spring. Initially the spring biases the sleeve to a closed position in which the ports are misaligned. The drop ball causes the sleeve to move to a position where the ports

align due to a build up of pressure behind the ball, and fluid is discharged radially through the ports. A small steel ball is then dropped into the tool which seals the radial ports and the consequential pressure build up extrudes the deformable ball through the ball seat. The steel ball will drop with the deformable ball and both are retained in a ball catcher at the base of the tool. When the balls drop together the spring biases the sleeve back to the closed position and the tool can be operated repeatedly.

A disadvantage of this tool is that it requires both a deformable ball and a smaller metal ball to operate. Care must then be taken to ensure the balls are dropped in the correct order. The smaller metal ball must lodge in the second, radial, outlet in order to stop flow and thus the tool is restricted to having a single radial port. This limits the amount of fluid which can be circulated as, in operation, all fluid flow must be redirected from the tool through the single port. Yet further is a disadvantage in that use of a rubber or deformable ball is unreliable as the material can break up or wear within the well bore.

It is an object of the present invention to provide an actuation mechanism for a downhole tool which obviates or mitigates at least some of the disadvantages of the prior art.

It is a further object of at least one embodiment of the present invention to provide an actuation mechanism to move a sleeve within a downhole tool.

It is a yet further object of at least one embodiment of the present invention to provide an actuation mechanism for use in a downhole tool which allows fluid flow through the tool to be maintained after actuation of the sleeve.

According to a first aspect of the present invention there is provided an actuation mechanism for a downhole tool, the mechanism comprising a substantially cylindrical body having a central bore running axially therethrough, a sleeve including ball restraining means slidably located within the bore and a non-pliable ball; wherein the sleeve is fixed to the body in a first position by retaining means and the ball locates in the ball restraining means to temporarily prevent a majority of fluid flow through the sleeve and cause the retaining means to release the sleeve to move to a second position at which the ball is discharged from the restraining means.

Preferably the retaining means is a shearable means. More preferably the shearable means is a shear pin. Thus at sufficient pressure the pin will shear and allow the sleeve to move from the first position to the second position.

Preferably also the body includes a stop. Preferably the stop is a ledge on an inner surface of the body which limits axial movement of the sleeve when the sleeve is in the second position.

Preferably the ball is spherical. More preferably the ball is formed from a non-pliable material and thus cannot deform. Advantageously the ball is made of steel.

In a first embodiment, the ball restraining means comprises a helical channel on an inner surface of the sleeve. Preferably the ball is sized to run in the helical channel in the direction of fluid flow to prevent a majority of fluid flow through the sleeve and cause the sleeve to move to the second position.

When the ball is dropped in the body, fluid will drive the ball into the channel and into the helical path. As the ball is sized for the channel it will block the majority of the fluid path through the tool and consequently pressure will build up on the ball. This pressure will be sufficient to shear the shear pin and the ball and sleeve will move together in the direction of fluid flow. The movement of the sleeve actuates the tool. The sleeve will stop at the second position and the ball will travel out of the channel.

Preferably the helical channel has curved walls. This will prevent damage to the ball. Preferably also the ball is sized to provide a fluid by-pass around the ball when in the channel. The ensures a positive pressure is maintained behind the ball and prevents chattering of the ball in the channel.

The helical channel may be considered as a screw thread. Thus the channel has a left hand thread so that the ball travels in the opposite direction to the rotation of the

tool on a work string. Preferably a pitch of the thread is greater than or equal to a diameter of the ball.

Preferably also the sleeve includes a conical surface at an entrance to the channel. This funnels the ball into the channel and ensures it travels into the helical path.

In a second embodiment the ball restraining means is an expandable ball seat. When the ball is dropped in the body, the ball will locate in the ball seat. The ball will block the fluid path through the tool and consequently pressure will build up on the ball by fluid travelling through the body. This pressure will be sufficient to shear the retaining means and move the ball and sleeve together to the second position. The movement of the sleeve actuates the tool. When the sleeve is stopped increased pressure will expand the expandable ball seat and release the ball.

Preferably the expandable ball seat includes a part conical surface having an aperture therethrough. Advantageously the aperture has a diameter less than a diameter of the ball. Preferably the ball seat is made of a flexible material, so that at a predetermined pressure it flexes to release the ball. Advantageously the ball seat is made of a metal so that the seat is not prone to wear during use. The ball seat may comprise a spring such as a disc spring.

Optionally the ball seat may be of a layered structure. Preferably the layered structure comprises a plurality of disc springs. Advantageously the disc springs are arranged oppositely in the structure to provide flex.

According to a second aspect of the present invention there is provided a downhole tool for circulating fluid in a borehole, the tool comprising a substantially cylindrical body having a central bore running axially therethrough, the body including at least one first port arranged substantially transversely to the central bore, a sleeve located within the bore, the sleeve including at least one second port arranged transversely to the central bore for discharging fluid from the central bore when the first and second ports are aligned, the sleeve further including ball restraining means, and a non-pliable ball, wherein the sleeve is fixed to the body in a first position by retaining means and the ball locates in the ball restraining means to temporarily prevent a majority of fluid flow through the sleeve and cause the retaining means to release the sleeve to move to a second position at which the ball is discharged from the restraining means and wherein the ports are aligned in one of the first or second position.

Thus the tool can be open for circulating purposes and then be closed by dropping the ball, or alternatively, can be closed with all fluid flow through the central bore and then opened to circulate fluid radially from the tool. In both cases the ball is released and can travel through the work string to operate a tool located downhole of the circulating tool.

Preferably the retaining means is a shearable means. More preferably the shearable means is a shear pin. Thus at sufficient pressure the pin will shear and allow the sleeve to move from the first position to the second position.

Preferably also the body includes a stop. Preferably the stop is a ledge on an inner surface of the body which limits axial movement of the sleeve when the sleeve is in the second position.

Preferably the ball is spherical. More preferably the ball is formed from a non-pliable material and thus cannot deform. Advantageously the ball is made of steel.

Preferably said first and second ports are located substantially perpendicular to a longitudinal axis through the tool. More preferably there are a plurality of said first and said second ports. Advantageously there are three or more said first and said second outlets. Preferably also said first and said second outlets are spaced equidistantly around the body and the sleeve respectively.

In a first embodiment, the ball restraining means comprises a helical channel on an inner surface of the sleeve. Preferably the ball is sized to run in the helical channel in the direction of fluid flow to prevent a majority of fluid flow through the sleeve and cause the sleeve to move to the second position.

When the ball is dropped in the body, fluid will drive the ball into the channel and into the helical path. As the ball is sized for the channel it will block the majority of the fluid path through the tool and consequently pressure will build up on the ball. This pressure will be sufficient to shear the shear pin and the ball and sleeve will move together in the direction

of fluid flow. The movement of the sleeve actuates the tool. The sleeve will stop at the second position and the ball will travel out of the channel.

Preferably the helical channel has curved walls. This will prevent damage to the ball. Preferably also the ball is sized to provide a fluid by-pass around the ball when in the channel. The ensures a positive pressure is maintained behind the ball and prevents chattering of the ball in the channel.

The helical channel may be considered as a screw thread. Thus the channel has a left hand thread so that the ball travels in the opposite direction to the rotation of the tool on a work string. Preferably a pitch of the thread is greater than or equal to a diameter of the ball.

Preferably also the sleeve includes a conical surface at an entrance to the channel. This funnels the ball into the channel and ensures it travels into the helical path.

In a second embodiment the ball restraining means is an expandable ball seat. When the ball is dropped in the body, the ball will locate in the ball seat. The ball will block the fluid path through the tool and consequently pressure will build up on the ball by fluid travelling through the body. This pressure will be sufficient to shear the retaining means and move the ball and sleeve together to the second position. The movement of the sleeve actuates the tool. When the sleeve is stopped increased pressure will expand the expandable ball seat and release the ball.

Preferably the expandable ball seat includes a part conical surface having an aperture therethrough. Advantageously the aperture has a diameter less than a diameter of the ball. Preferably the ball seat is made of a flexible material, so that at a predetermined pressure it flexes to release the ball. Advantageously the ball seat is made of a metal so that the seat is not prone to wear during use. The ball seat may comprise a spring such as a disc spring.

Optionally the ball seat may be of a layered structure. Preferably the layered structure comprises a plurality of disc springs. Advantageously the disc springs are arranged oppositely in the structure to provide flex.

Optionally the tool may include ball collecting means. The ball collecting means may be an element located in the body to prevent passage of the ball through the tool, but allowing passage of fluid through the tool.

According to a third aspect of the present there is provided a method of actuating a tool in a borehole, the method comprising the steps;

(a) inserting in a work string a tool including an actuating mechanism according to the first aspect;
(b) running the work string and tool into a borehole, with the tool in a first operating position;
(c) dropping the non pliable ball into the work string such that the ball is temporarily restrained in the sleeve and by virtue of an increase in pressure on the ball, forcing the sleeve to move and switching the tool to a second operating position; and

(d) discharging the ball from the sleeve.

In a first embodiment, the step of temporarily restraining the ball comprises passing the ball along a helical channel in the sleeve.

In a second embodiment, the step of temporarily restraining the ball comprises the steps of locating the ball in an expandable ball seat and then, by virtue of the increase in pressure on the ball expanding the ball seat and releasing the ball when the tool is in the second operating position.

Preferably also, the method further includes the step of actuating a second tool located below the first tool when the ball is discharged.

Optionally, the method may include the step of catching the dropped ball in the work string.

According to a fourth aspect of the present invention there is provided a method of circulating fluid in a borehole, the method comprising the steps:

(a) inserting in a work string a tool including an actuating mechanism according to the second aspect;
(b) running the work string and tool into a borehole, with the tool in a closed position wherein the ports are misaligned and fluid flows through the central bore;
(c) dropping the non pliable ball into the work string such that the ball is temporarily restrained in the sleeve and by virtue of an increase in pressure on

the ball, forcing the sleeve to move and switching the tool to an open position wherein the ports are aligned;

(d) discharging fluid from the ports; and

(e) discharging the ball from the sleeve.

In a first embodiment, the step of temporarily restraining the ball comprises passing the ball along a helical channel in the sleeve.

In a second embodiment, the step of temporarily restraining the ball comprises the steps of locating the ball in an expandable ball seat and then, by virtue of the increase in pressure on the ball expanding the ball seat and releasing the ball when the tool is in the open position.

Preferably also, the method further includes the step of actuating a second tool located below the first tool when the ball is discharged.

Optionally, the method may include the step of catching the dropped ball in the work string.

According to a fifth aspect of the present invention there is provided a method of circulating fluid in a borehole, the method comprising the steps:

(a) inserting in a work string a tool including an actuating mechanism according to the second aspect;

(b) running the work string and tool into a borehole, with the tool in an open position wherein the ports

are aligned and fluid is discharged through the ports;

(c) dropping the non pliable ball into the work string such that the ball is temporarily restrained in the sleeve and by virtue of an increase in pressure on the ball, forcing the sleeve to move and switching the tool to a closed position wherein the ports are misaligned;

(d) discharging the ball from the sleeve; and

(e) flowing fluid through the central bore.

In a first embodiment, the step of temporarily restraining the ball comprises passing the ball along a helical channel in the sleeve.

In a second embodiment, the step of temporarily restraining the ball comprises the steps of locating the ball in an expandable ball seat and then, by virtue of the increase in pressure on the ball expanding the ball seat and releasing the ball when the tool is in the closed position.

Preferably also, the method further includes the step of actuating a second tool located below the first tool when the ball is discharged.

Optionally, the method may include the step of catching the dropped ball in the work string.

Embodiments of the present invention will now be described, by way of example only, with reference to the following Figures, of which:

Figure 1 is a part cross-sectional view of a downhole tool in a first position according to a first embodiment of the present invention;

Figure 2 is a part cross-sectional view of the downhole tool of Figure 1 in a second position;

Figure 3 is a part cross-sectional view of a downhole tool in a first position according to a second embodiment of the present invention;

Figure 4 is a part cross-sectional view of the downhole tool of Figure 3 in a second position; and

Figures 5 is a schematic illustration a downhole tool according to the present invention on a work string.

Reference is initially made to Figure 1 of the drawings which illustrates a downhole tool, generally indicated by reference numeral 10, in accordance with an embodiment of the present invention. Tool 10 includes a cylindrical body 12 having an upper end 14, a lower end 16 and a cylindrical bore 18 running therethrough. The body 12 has a box section 20 located at the upper end 14 and a pin section 22 located at the lower end 16 for connecting the tool 10 in a work string or drill string (not shown).

The body 12 further includes four radial ports 24 located equidistantly around the body 12. The ports 24 are perpendicular to the bore 18.

Located on an inner surface 25 of the body 12 are two opposing ledges 26, 28 used to limit axial movement of a

sleeve 30 located within the body 12. Sleeve 30 is sealed against body 12 by o-rings 31a-b.

Sleeve 30 is an annular body which also includes four radial ports 32 located equidistantly around the sleeve 30. The ports 32 are perpendicular to the bore 18. The ports 32 are of a similar size to the ports 24 in the body 12.

At an upper end 36 of the sleeve 30 is located a conical surface 38 facing the upper end 14 of the tool 10. Downwardly extending from the conical surface is a helical channel 34. The channel 34 comprises a continuous spiral groove, having curved walls 40, which takes the path of a screw thread on the inner surface 39 of the sleeve 30. The handedness of the 'screw thread' is left handed.

Located between the outer surface 44 of the sleeve 30 and the inner surface 46 of the body 12 is a shear pin 48. Though a single shear pin is shown it will be appreciated that any number of shear pins could be used. The shear pin fixes sleeve 30 to the body 12.

Reference is now made to Figure 2 of the drawings which illustrates the tool 10 of Figure 1, now with a ball 68 discharged from the bore 42. Like parts to those of Figure 1 have been given the same reference numeral for ease of identification. Ball 68 is sized to travel along the helical channel 34. Ideally the ball 68 is sized to have a diameter less than or equal to the pitch of the screw thread forming the walls 40 of the channel 34. In this way when the ball 68 travels along the channel 34 a

by-pass is created between the edge of the ball 68 and the walls 40 of the channel 34. The ball is of a hard material which is non-pliable. Ideally the ball is made of a metal such as steel.

In use, tool 10 is connected to a work string using the box section 20 and the pin section 22. As shown in Figures 1, this is referred to as the first position of the tool 10. In this position, sleeve ports 32 are aligned with body ports 24, and fluid flow is both through the bore 42 of the tool 10 and circulating out through the radial ports 24,32. The tool 10 is then run into a bore hole cleaning the bore hole casing or circulating the fluid through the tool as required.

Drop ball 68 is then released through the bore of the work string from a surface. Ball 68 travels by fluid pressure to the conical surface 38 at the upper end 36 of the sleeve 30. The ball 68 is funnelled into the helical channel 34 where its progress is arrested. As the ball 68 is now blocking the majority of fluid flow through the bore 18, fluid pressure will build up behind the ball and force the ball along the helical channel 34. Due to the size of the ball a small amount of fluid will be allowed to by-pass the ball 68. This fluid by-pass ensures that a positive pressure is maintained behind the ball 68 so that the ball 68 does not flow towards the upper end 14 of the tool 10 also prevents the ball 68 from 'chattering' in the channel 34. As the ball 68 makes its way along the channel 34 it acts as a temporary flow restrictor allowing sufficient pressure to build up on the ball 68 and sleeve 30 such that the shear pin 48 shears and releases the sleeve 30 from the body 12. The

sleeve and ball will move until the sleeve comes to a stop at the ledge 28. Increased pressure will force the ball through the remainder of the channel 34 whereupon it will be released from the sleeve 30. This is as shown in Figure 2 and referred to as the second position. In this position the ports 24, 32 are now misaligned and fluid flow is entirely through the bore 18.

Thus in the first position the tool is in an open configuration and fluid is circulated radially from the tool. In the second position, the tool is in a closed configuration and fluid flow is entirely through the central bore of the tool.

It will be appreciated by those skilled in the art that by relocating the position of the ports 32 on the sleeve 30 or the ports 24 on the body 12, the tool 10 can be arranged such that the tool is closed in the first position and open in the second position.

The principal advantage of this embodiment of the present invention is that it provides an actuating mechanism which can be repeatedly operated in a downhole tool. Further the mechanism dispenses with the need for a ball seat having a diameter smaller than the diameter of the drop ball and thus the flow through area of a tool incorporating the mechanism is improved over prior art drop ball actuated tools.

Reference is now made to Figure 3 of the drawings which illustrates a downhole tool, generally indicated by reference numeral 100, in accordance with a second embodiment of the present invention. Like parts to the

tool 10 of Figures 1 and 2 have been given the same reference numeral with the addition of 100.

Tool 100 includes a cylindrical body 112 having an upper end 114, a lower end 116 and a cylindrical bore 118 running therethrough. The body 112 has a box section 120 located at the upper end 114 and a pin section 122 located at the lower end 116 for connecting the tool 100 in a work string or drill string (not shown).

The body 112 further includes four radial ports 124 located equidistantly around the body 112. The ports 124 are perpendicular to the bore 118.

Located on an inner surface 125 of the body 112 are two opposing ledges 126, 128 used to limit axial movement of a sleeve 130 located within the body 112. Sleeve 130 is sealed against body 112 by o-rings 131a-b.

Sleeve 130 is an annular body which also includes four radial ports 132 located equidistantly around the sleeve 130. The ports 132 are perpendicular to the bore 118. The ports 132 are of a similar size to the ports 124 in the body 112.

At an upper end 136 of the sleeve 30 is located an expandable ball seat 83. A conical surface 88 of the seat 83 faces the upper end 114 of the tool 100. The conical surface 88 is part of a disc spring 84 mounted at the upper end 136 of the sleeve 130. The spring 84 is placed in facing the lower end 116 of the tool 100 such that it operates opposite to its typical arrangement. Spring 84 may comprise a stack of disc springs selected to provide

the a deflection or flex in structure at a desired pressure. Each spring is alternately arranged in the stack. Disc springs, and in particular disc springs formed from conical shaped washers (sometimes referred to as Belleville washers) as used here, are well known to those skilled in the art. Such springs are available from, for example, Belleville Springs Ltd, Redditch, United Kingdom. An advantage of these springs is that they return to their original shape following deflection.

Located between the outer surface 144 of the sleeve 30 and the inner surface 146 of the body 12 is a shear pin 148 which fixes the sleeve 130 and the body 112 together when the tool is first deployed.

Reference is now made to Figure 4 of the drawings which illustrates the tool 100 of Figure 3, now with a ball 168 discharged from the bore 118 having travelled through the tool 100. Like parts to those of Figure 3 have been given the same reference numeral for ease of identification. The ball 168 has passed through the tool 100 where it located on the expandable ball seat 83 and is sized to block the bore 18. In this way the ball 168 was arrested and pressure built up behind the ball 168. This pressure moved the ball 168 and sleeve 130 together within the body 12 to the position illustrated. At this point, the sleeve 130 is stopped on the ledge 128. Increased pressure causes the seat 83 to expand by flexing which discharges the ball 168 from the seat 83 and the ball 168. This leaves the sleeve 130 in a position such that the ports 124, 132 are misaligned.

In use, tool 100 is connected to a work string using the box section 120 and the pin section 122. As shown in Figure 1, which is referred to as the first position, sleeve ports 132 are located at the same axial position as the body ports 124, thus fluid can circulate radially from the tool 100. The tool 100 is then run into a bore hole cleaning the bore hole casing or circulating the fluid through the tool as required.

Drop ball 168 is then released through the bore of the work string from a surface. Ball 168 travels by fluid pressure to the conical surface 88 at the upper end 136 of the sleeve 130. The ball 168 lands on the seat 83 where its progress is arrested. As the ball 168 is now blocking the fluid flow through the bore 118, fluid pressure will build up behind the ball and allow sufficient pressure to build up on the ball 68 and sleeve 30 such that the pin 148 will shear and the sleeve 130 is free to move independently of the body 112. The sleeve 130 and ball 168 will move downwards until the sleeve abuts the ledge 128.

On increasing fluid pressure on the ball 168, with the sleeve 130 now arrested, pressure is exerted on the ball seat 83. The disc spring 84 will deflect under this increased pressure and eject the ball 168 into the bore 118 below the seat 83. The seat 83 will return to its original shape. The ball 168 exits the seat 83 and free falls from this point, exiting the tool 100 at the lower end 116. This is as shown in Figure 2 and referred to as the second position. In this position the ports 124, 132 are now misaligned and fluid flow is entirely through the bore 118.

Thus in the first position the tool is in an open configuration and fluid is circulated radially from the tool. In the second position, the tool is in a closed configuration and fluid flow is entirely through the central bore of the tool.

It will be appreciated by those skilled in the art that by relocating the position of the ports 132 on the sleeve 130 or the ports 124 on the body 112, the tool 100 can be arranged such that the tool is closed in the first position and open in the second position.

The principal advantage of the second embodiment of the present invention is that it provides an actuating mechanism which can be operated using a metal ball instead of a deformable ball. In this way pumped fluid flow is not required to land the ball in the seat and thus the tool can be operated without the need to pump.

Reference is now made to Figure 5 of the Figures, which illustrates a downhole tool, generally indicated by reference numeral 200, according to the present invention in a work string 210. Tool 200 is as described with reference to Figures 1 and 2 or 3 and 4. The tool 200 is located on a work string 210 which is run in a well bore 220. Located below the tool 200 is a hydraulically operated tool 230 as is known the art. In the embodiment shown the tool 230 is a liner hanger operated by a drop ball mechanism. Below the tool 230 is an optional ball catcher 240 for collecting any dropped balls which have passed through the tools 200, 230. Ball catcher 240 is as known in the art.

In use, the tools 200, 230, 240 are located on the work string 210. Work string 210 is run in the well bore 220 with ports 250 in the circulating tool 200 in an open configuration. In this way fluid is circulated out of the work string 210 at the ports 250. At a position where the liner hanger 230 is required, a drop ball is passed into the work string 210 from a surface of the well bore 220. The ball will actuate the tool 200 from an open position to a closed position. Fluid flow is then entirely through the work string 210. Once the closed configuration is achieved the ball, exits from the tool 200 and enters a central bore of the tool 230. Here the ball actuates the liner hanger. If required the ball can be prevented from further passage through the work sting 210 by being received in the ball catcher 240 on exiting the hanger 230.

The principal advantage of this embodiment of the present invention is that it provides a circulating tool in which multiple balls could be passed through the tool once the tool is in the second position. These balls can thus be used to operate tools arranged below the circulation tool.

It will be appreciated that although the description refers to relative positions as being 'above' and 'below', the tool of the present invention can equally well be used in horizontal or inclined boreholes and is not restricted to vertical boreholes. Additionally the term 'borehole' can be used to refer to an open, cased or lined well bore.

Various modifications may be made to the invention herein described without departing from the scope thereof. For example, radial ports could be located at longitudinal spacings on the tool to provide radial fluid flow across a larger area when the ports are open. The ports may have varying diameters which may provide a nozzle on the outer surface of the body to increase fluid velocity.

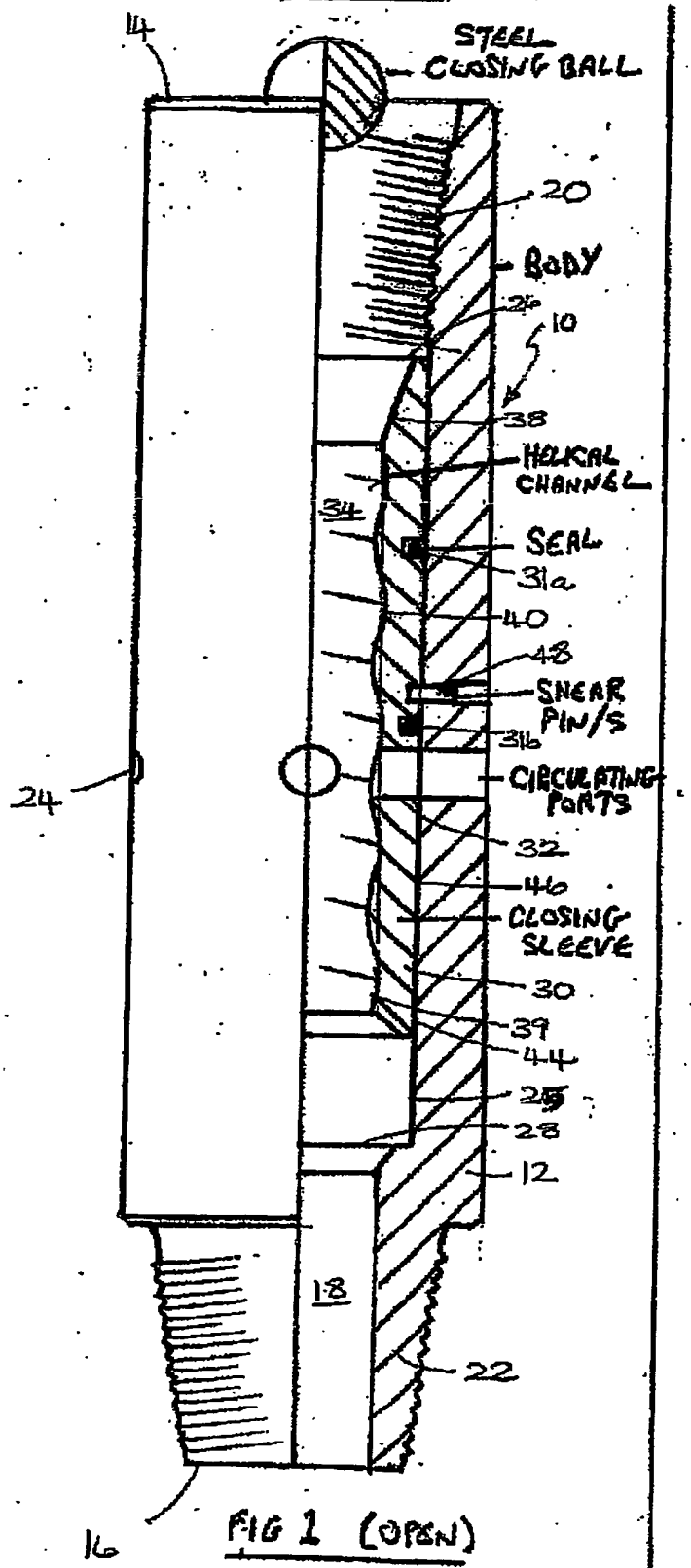

FIG 1 (OPEN)

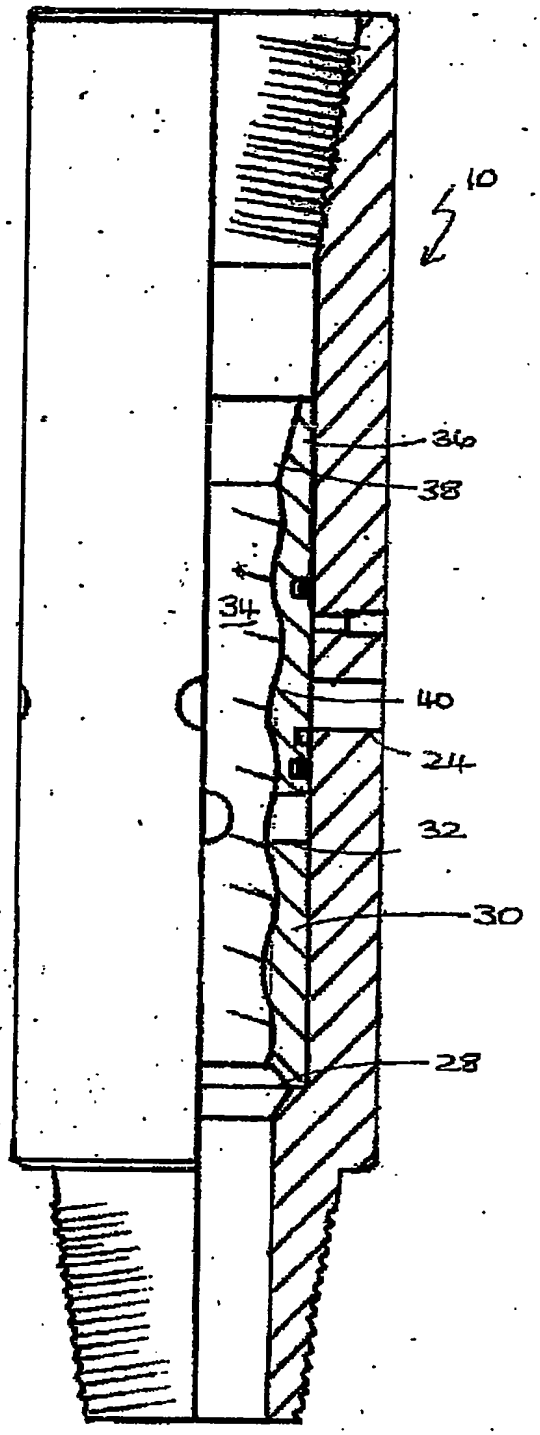

FIG 2 (CLOSED)

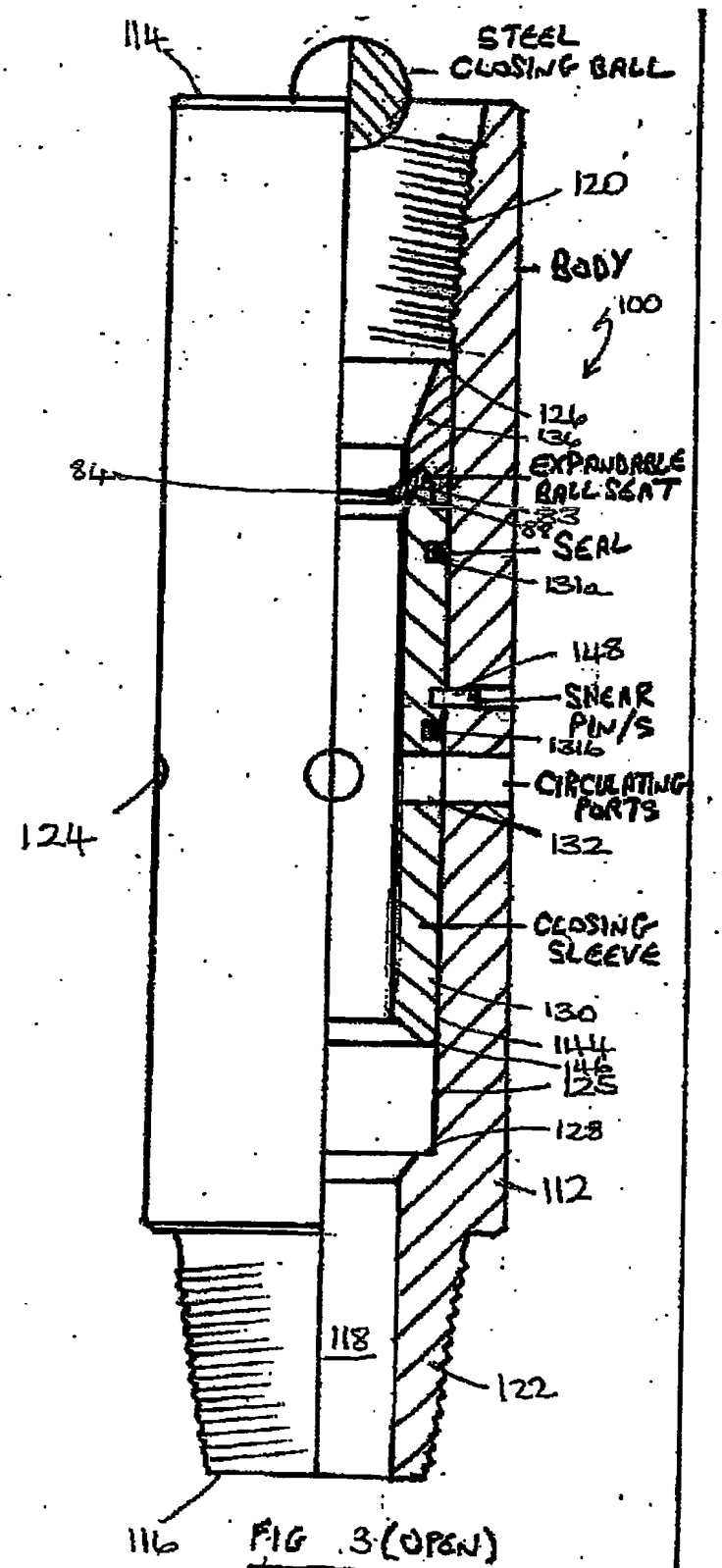

FIG 3 (OPEN)

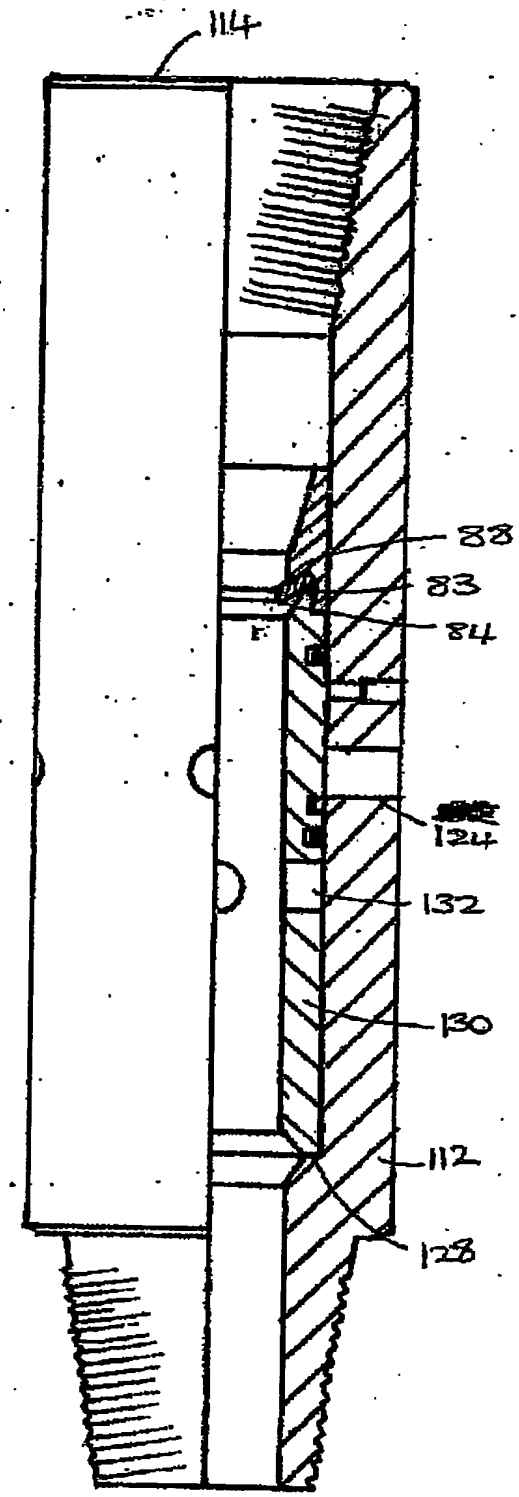

FIG 4 (CLOSED)

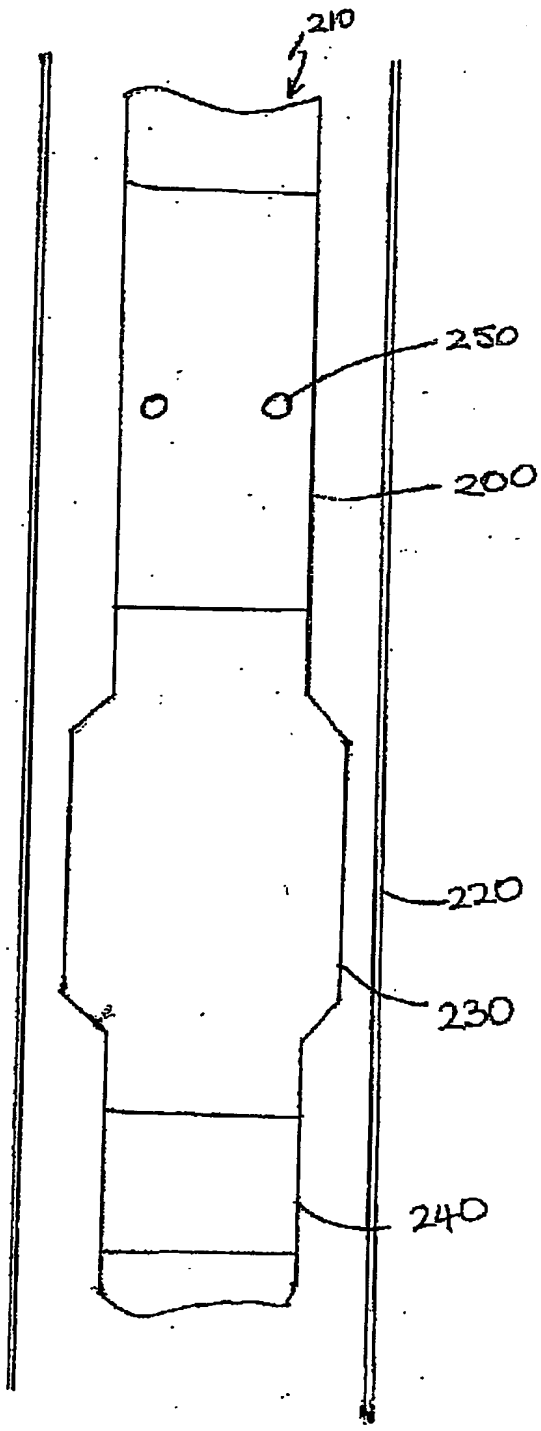

Fig 5